



Educational Brief

CASSINI SCIENCE INVESTIGATION

Scattering: Seeing the Microscopic Among the Giants

Objective

To demonstrate how light waves passing through a medium can be used to determine the sizes of particles within the medium.

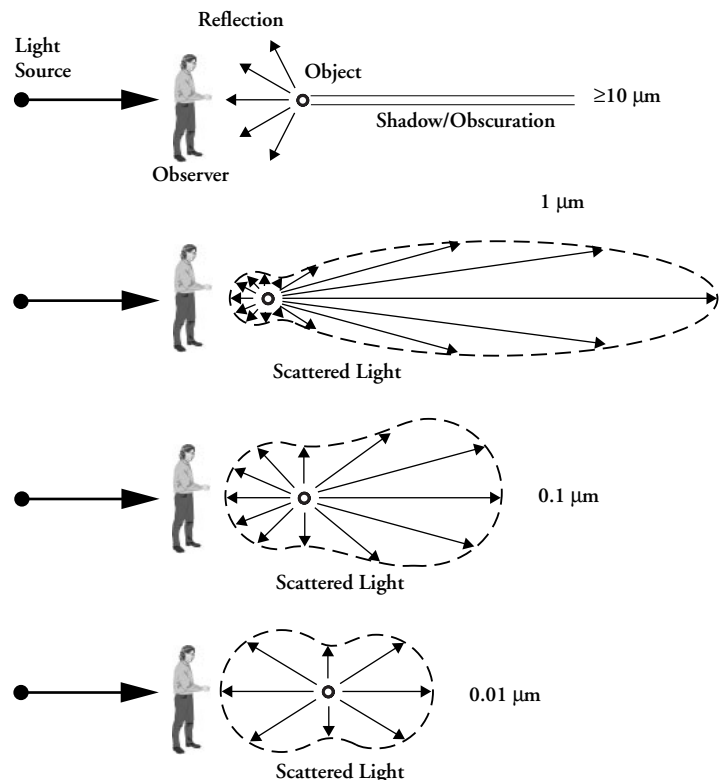
Time Required: 1 hour

Saturn System Analogy: Rings and Atmospheres of Saturn and Titan

Keywords: Aerosols, Obscuration, Particles, Reflection, Ring Spokes, Scattering, Shadow

MATERIALS

- Laser pointer (preferred; small focusable flashlight will work if laser is not available)
- Two large binder clips
- Two clear plastic or glass water bottles or cups (walls should be vertical), 50–100 millimeters in diameter (bottled-water or soft drink bottles are good as long as they have some noncorrugated surface)
- Tap water
- Milk (1/20 teaspoon per 12 ounces of water)
- Eye dropper
- Flour (less than or equal to 1/4 teaspoon – a “pinch” – per 12 ounces of water)
- Lazy Susan turntable (optional but helpful)
- Masking, duct, or electrical tape



Light striking an object is reflected or scattered depending on the object's size. In each example, the amount of light sent in each direction is indicated by the length of the arrow. Objects larger than about 10 micrometers reflect light and create shadows. Objects about 1/100 micrometer in size scatter equal amounts of light back toward the source and away from the source, and lesser amounts in other directions. Objects about 1 micrometer in size exhibit strong forward scattering and weak backscattering.

Discussion

Our everyday view of the world relies on the reflection of light from the objects around us. This reflection is called “backscatter” when it is coming from small objects, and especially when the light source is *behind* the observer. Very tiny

objects, approximately the size of the light source's wavelength, also send light *forward*, that is, *continuing from the source and away from the observer*. This effect, called “forward scattering,” is useful to scientists in determining the sizes of particles in planetary atmospheres and ring systems.

Procedure

Adhere a piece of tape to one side of each container. Fill one container with water and place it on a Lazy Susan. In the other container, prepare a highly dilute solution of milk, thoroughly mixed so the water is just slightly whitened. (Start with 1/20 teaspoon of milk per 12 ounces of water; find the right proportions by experimentation in advance.) Use the binder clips as legs for the laser pointer, with one of them holding the laser's switch in the “on” position. Place the laser and sample bottle on the Lazy Susan.

CAUTION: BE CAREFUL NOT TO PROJECT THE LASER BEAM INTO ANYONE'S EYES. EYE DAMAGE CAN RESULT!

Align the laser pointer so that the beam passes through the water bottle and projects onto the piece of tape on the far side of the container. (The tape will ensure that the laser beam is not projected farther into the room and perhaps into someone's eyes.)

Darken the room, if possible. Project the laser beam through the container of plain water. Observe the brightness of the beam in the water as the Lazy Susan is rotated. The beam should pass straight through and be invisible or nearly so from all directions except directly along the beam.

Next, project the beam through the dilute milk solution. Laser light scattering from tiny particles of milk will delineate the laser beam. The intensity of the beam is stronger or weaker according to the scattering properties of the milk particles (primarily their size) as the assembly is turned in front of fixed observers. Observers should note how the beam reaches maximum brightness when they are looking in nearly the direction it is coming from.

Mix flour with the plain water (less than or equal to 1/4 teaspoon flour per 12 ounces of water) in the first container.

Project the laser beam through the dilute flour solution. The scattering properties of the milk and flour solutions are different because there is greater variation in flour particle size than in milk particle size. Store-bought milk is homogenized (its particles are reduced to the same size) so the cream stays in solution. With either mixture, notice how the beam intensity diminishes with distance (looking from the side).

As an everyday terrestrial example, recall that bright headlights in fog may or may not help drivers, depending on particle size. Reflections from large fog droplets make night visibility with bright headlights poorer than with dimmed headlights.

Additional Experiments and Questions

Try other materials that will remain suspended in liquid for useful amounts of time. Corn meal, corn starch, oat bran, silt from a local stream bed, glitter, salt, and sugar will provide varying results. Try transparent carbonated beverages, including their foams, and smoke trapped in a jar. Which work? Which don't? Why? Estimate particle sizes in gelatin based on its scattering properties. Can you detect different particle shapes based on scattering?

A simple photometer can be used to compare the brightness of the beam as a function of the viewing angle. Mount a solar cell on one end of an empty toilet paper tube so the tube shades the light-sensitive surface from ambient light. Attach the leads to a millivolt meter (or multimeter). With the sample bottle centered on the Lazy Susan, align the laser on the Lazy Susan so it shines through the center of the bottle and onto the solar cell.

Record voltage measurements every 30 degrees around the full circle for each sample bottle. Plot the voltage as a proportioned line segment every 30 degrees around a point. Diluted milk will produce a pattern like the 1-micrometer pattern illustrated on the front of this Educational Brief.

Several vendors offer light-measuring photometry systems that acquire data and plot it under computer control. Such systems can be adapted for quantitative measurements of the sample bottles in this activity. Computerized data acquisition is common in many laboratories.



Is the color of the daylight sky related to sunset colors and scattering?

Because scattering is a phenomenon dependent on both the wavelength of the wave being scattered and on the size of the scatterer, much can be learned by working in well-separated parts of the electromagnetic spectrum. Where light waves tell us about the sizes of small particles, radio waves can tell us about the sizes of objects ranging in size from golf balls to houses.



This picture of Titan taken by Voyager 2 shows sunlight scattered by aerosols in Titan's atmosphere all around the satellite. If there were no atmosphere to scatter light, only a thin crescent, like the Moon just past new, would be visible. A fuzzy tennis ball shows a similar effect when viewed with a single, compact bright light in the background.

Science Standards

A visit to the URL <http://www.mcrel.org> yielded the following standards and included benchmarks that may be applicable to this activity.

8. Understands the structure and properties of matter.

LEVEL 1 (GRADES K-2)

Knows that different objects are made up of many different types of materials (e.g., cloth, paper, wood, metal) and have many different observable properties (e.g., color, size, shape, weight).



Knows that things can be done to materials to change some of their properties (e.g., heating, freezing, mixing, cutting, dissolving, bending), but not all materials respond the same way to what is done to them.

LEVEL 2 (GRADES 3-5)

Knows that substances can be classified by their physical and chemical properties (e.g., magnetism, conductivity, density, solubility, boiling and melting points).

Knows that materials may be composed of parts that are too small to be seen without magnification.

12. Understands the nature of scientific inquiry.

LEVEL 1 (GRADES K-2)

Knows that learning can come from careful observations and simple experiments.

LEVEL 2 (GRADES 3-5)

Knows that scientific investigations involve asking and answering a question and comparing the answer to what scientists already know about the world.

Knows that scientists use different kinds of investigations (e.g., naturalistic observation of things or events, data collection, controlled experiments), depending on the questions they are trying to answer.

Plans and conducts simple investigations (e.g., formulates a testable question, makes systematic observations, develops logical conclusions).

LEVEL 3 (GRADES 6-8)

Establishes relationships based on evidence and logical argument (e.g., provides causes for effects).

LEVEL 4 (GRADES 9-12)

Knows that, when conditions of an investigation cannot be controlled, it may be necessary to discern patterns by observing a wide range of natural occurrences.

Teachers — Please take a moment to evaluate this product at http://ehb2.gsfc.nasa.gov/edcats/educational_brief. Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.

Student Worksheet — Scattering: Seeing the Microscopic Among the Giants

Procedure

Your teacher will set up the experiment.

The teacher will shine the laser through a glass of water.
What do you see as the glass is rotated?

The teacher will then add milk, flour, or some other substance. How does the laser beam change as it passes through the water mixture?

The teacher will experiment with different substances in the water. Observe how the beam changes as each different material is used.

Questions

What are some examples of light scattering in everyday life?

Which substances demonstrate scattering? Which don't?

